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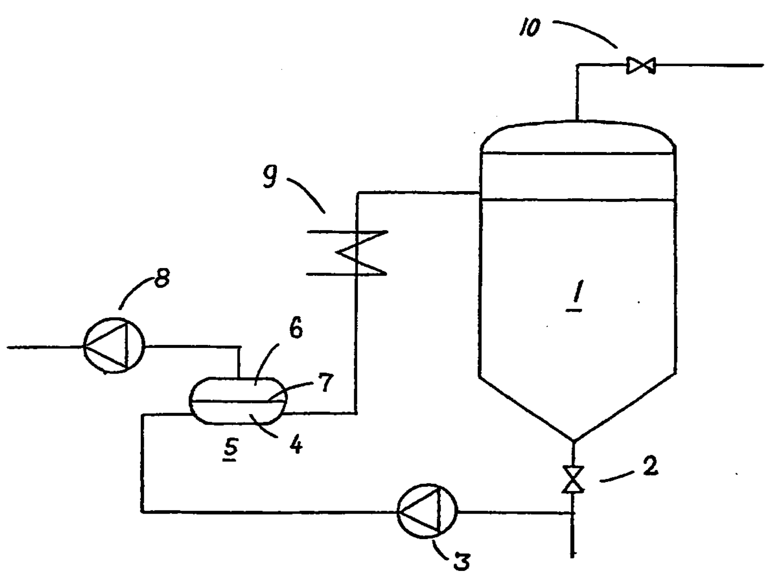
(54) **Title:** PROCESS FOR REDUCING OR AVOIDING PRODUCTION OF FOAM ON THE SURFACE OF A FERMENTING WORT



(57) **Abstract:** A process for reducing or avoiding production of foam on the surface of a fermenting wort is provided, comprising recovering a flow from a fermenter containing a fermenting wort, treating the flow in a membrane module comprising a membrane allowing the passage of CO_2 so as to produce a retentate having a reduced CO_2 content, and recycling the retentate to the fermenter.

WO 00/78916 A1

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PROCESS FOR REDUCING OR AVOIDING PRODUCTION OF FOAM ON THE SURFACE OF A FERMENTING WORT

The present invention relates to a process for reducing or avoiding production of foam on the surface of a fermenting wort.

Beer is traditionally produced from germinated barley (malt), water, yeast, hops, and, possibly, raw grain. The germinated barley is initially ground so that the endosperm is laid open, whereupon a mashing takes place. By the mashing, the ground malt, water, and, possibly, raw grain are mixed in a container, and, subsequently, a heat treatment is carried out. The heat treatment may follow various routes temperature depending on the malt enzymes desired to be most active. During the mashing, the starch of the malt and the raw grain is converted into fermentable carbohydrates.

After the mashing the liquid phase referred to herein as the wort is separated from the insoluble components called the spent grain. The wort is then boiled with hops (wort boiling) or hops extract is added. The wort contains dissolved solids, referred to herein as the extract. The extract has a high content of fermentable carbohydrate types.

Following the admixture of yeast, the wort is led to a fermenter. During the fermentation, the fermentable part of the extract is mainly converted into ethanol and CO_2. Since the solubility of CO_2 in the wort is relatively low, gas bubbles will generate and rise to the surface of the fermenting wort. While rising, the gas bubbles will carry away various wort components, especially proteins and bitter compounds, whereby a foam is produced on the surface of the fermenting wort.

The production of said foam is undesirable for several reasons. First of all, the wort filling level will suffer because there has to be room enough for the foam above the surface of the fermenting wort. Thus, the typical filling level is 85%. Secondly, some of the taste and flavour compounds are carried upwards into the foam layer. In particular, the bitter compounds deriving from the hops tend to be carried upwards into the foam layer so that the utilization of the hops admixed during the boiling becomes less than optimally. Finally, due to the removal of the foam during and after fermentation a so-called foam trap has to be established as a special measure in connection with the CO_2 recovery process.

Various processes for reducing the production of foam in a fermenting wort have been suggested in the prior art. In European Patent No. 0 017 650 it is suggested to place a layer of floats on the surface of the fermenting wort, said floats having an eccentric centre of gravity so that a stable floating capacity is obtained. The presence of such a layer of floats should restrain the production of a foam layer because foam components is deposited on top of the floats, whereby these turn around and return the foam components to the fermenting wort.

In German Publication No. 25 35 548 it is suggested to use a mechanical foam separator. The foam separator mainly comprises a number of rotating discs placed on a hollow shaft. The foam is disintegrated between the discs when influenced by the gravity into the gas and liquid/solid components. The liquid and solid components will be absorbed by the fermenting wort whereas the gas will escape through the hollow shaft.

While said suggestions for reducing foam above the

fermenting wort may to some extent be used to reduce a foam layer already produced, the prior art does not describe how the production of foam may be totally or partially avoided. As the person skilled in the art will realize, it is disadvantageous to have floats or a mechanical foam separator inside the fermenter since such means may involve the risk of contaminating the fermenting wort.

The object of the present invention is to provide a process wherein the production of foam is reduced or totally avoided when fermenting a wort. A further object is to provide a process which makes the presence of various means like floats or foam separators inside the fermenter unnecessary.

According to the present invention, said objects of are met in a process for reducing or avoiding production of foam on the surface of a fermenting wort comprising

- recovering a flow from a fermenter containing a fermenting wort,
- treating the flow in a membrane module comprising a membrane allowing the passage of CO_2 so as to produce a retentate having a reduced CO_2 content, and
- recycling the retentate to the fermenter.

The invention also relates to a plant for the fermentation of a wort while reducing or avoiding production of foam on the surface, said plant comprising a container for the wort fermentation, a membrane module having a chamber for retentate and a chamber for permeate separated by a membrane allowing passage of CO_2, means for providing a pressure difference over the membrane, means for providing liquid communication between the container for the wort fermentation and the retentate chamber, and means for recycling the retentate from the membrane module to the container for the

the wort fermentation.

The flow of fermenting wort from the fermenter is mainly recovered continuously. The recovery may take place from arbitrary portions of the fermenter but preferably the flow is recovered from the lower portion of the fermenter, in particular from the bottom portion, in order to avoid formation of a layer of precipitated dead or dying yeast cells. By the traditional brewing method, such a layer will be formed and result in not necessarily desired flavouring agents from the dead or dying cells being incepted by the fermenting wort.

The container for the fermenting wort may be of any arbitrarily suitable type. In modern production, fermenters having a size of about 500 m^3 are normally used. This leads to a considerable pressure on the liquid at the bottom of the fermenter. Thus, when recovering the fermenting liquid it is not always a must to use a pump to obtain the necessary pressure to convey the fermenting liquid to the membrane module. Usually it is preferred, however, to use a pump to adjust the pressure on the retentate side of the membrane.

Inside the membrane module, the fermenting wort is treated by being contacted with a membrane allowing the passage of CO_2. CO_2 is present as a dissolved component or as carbonic acid (H_2CO_3) within the fermenting wort, and, depending on the physical conditions, such as temperature, pressure, and concentration/ partial pressure of CO_2, possibly also as a separate gas phase. Usually, it is preferred to carry out the treatment under conditions wherein CO_2 is present as a dissolved component or as carbonic acid in the liquid to be treated inside the membrane module. The membrane is mainly characterized in that no component or only a

minor amount of the other components of the wort pass through same.

The membrane may be produced of various sorts of material. The membrane is preferably made of a polymer material but ceramic materials are applicable as well. Examples of polymer materials are polysulphone, polyamide, polyethylene, polypropylene, polytetrafluoroethylene, polyurethane, and cellulose acetate. The membrane is usually porous so that a number of pores appear through which CO_2 is transferred.

A porous membrane may be asymmetrical or dense. In an asymmetrical membrane, the pores are asymmetrical so that the diameters of the pores facing the feed flow are smaller than those of the pores facing the permeate. In a dense membrane, the pore diameters through the membrane are essentially constant. Usually, it is preferred to use asymmetrical membrane types since, at a given robustness of the membrane, the pressure loss over same is considerably lower than for dense membrane types.

On the permeate side of the membrane a gas or liquid fluid may circulate in which CO_2 is soluble or to which CO_2 may bond. The fluid on the permeate side has a lower pressure than that on the retentate side of the membrane so that over the membrane a driving force is provided. When conveyed from the retentate side to the permeate side of the membrane, CO_2 will dissolve in or bind to the circulating fluid. The fluid containing CO_2 may subsequently be regenerated so as to remove CO_2 by a suitable process, e.g. stripping, extraction, phase separation, heating, etc., after which the regenerated fluid is recycled into the membrane. A suitable fluid could be an aqueous solution of ions of a alkaline earth metal, e.g. an aqueous solution containing ions of magnesium, calcium, strontium, or

barium. A gaseous fluid may be used as a sweeping gas for the disposal of CO_2 passing through the membrane in order to reduce the partial pressure of CO_2 in the immediate vicinity of the membrane.

Preferably, however, a fluid is not circulated on the permeate side of the membrane. Instead a pressure considerably lower than that on the retentate side of the membrane is provided so that CO_2 passing through the membrane will be removed as a gas phase in the permeate.

If so desired, the amount of CO_2 removed from the fermenting wort may be recycled into the produced beer during the filtering and broaching process later on in the brewing process.

By the process according to the invention any suitable membrane module is applicable. Suitable membrane modules are for instance hollow fibre modules and so-called plate-and-frame modules. A hollow fibre module usually comprises a number of hollow fibres mainly provided in parallel in a cylindrical casing. At the end of the cylindrical casing, the hollow fibres are sealed by means of a suitable stopping means, thus defining a first chamber, which is delimited by the outer surface of the hollow fibres, the inside by the stopping means and the inside of the casing. A second chamber is constituted by the cavity of the hollow fibres.

The casing of a hollow fibre module is usually provided with inlet and outlet means for fluid. When flowing into the first chamber, the fermenting wort will get into contact with the outer surface of the hollow fibres. On the surface, a mas transfer will occur which allows CO_2 to pass into the membrane whereas the fermenting wort is predominantly retained. A provided pressure difference over the membrane is the

driving force through the membrane. The CO_2 passing through the membrane will travel into the second chamber defined above and be present in the permeate.

If desired, the two chambers may be inter-changed so that the fermenting wort is transferred into the cavity of the fibres and the permeate flows inside the cavity defined by the outside of the fibres, the inside of the casing, and the inside of the stopping means.

In case the membrane module used for the process according to the invention is of the plate-and-frame type, the first chamber is delimited by the inside of a frame and one side of a membrane whereas the second chamber is delimited by the inside of another frame and the other side of the membrane. A flow of fermenting wort is led into the first chamber through an inlet means and brought into contact with a first side of the membrane. A pressure difference provided over the membrane is the driving force for the transport of the CO_2 through the membrane.

If desired, the membrane may be provided with a suitable support in order that the membrane becomes sufficiently robust to withstand the pressure difference between the first and the second chamber. The pressure difference over the membrane is at least sufficient to ensure considerable transport of CO_2. Upwards, the pressure difference over the membrane is delimited by the physical destruction of the membrane structure. The pressure difference preferably amounts to 0.1 MPa to 10 MPa, especially between 0.5 and 5 MPa.

When treated in the membrane module, the retentate obtains a reduced CO_2 content. Before recycling into the fermenter, the retentate may be cooled, if desired.

The fermentation of the wort in the fermenter creates heat. In order to prevent the fermenting wort from being heated to an undesired level, a cooling of

the fermenter is usually provided by furnishing same with a cooling jacket. When establishing a new fermenter, it is cost-consuming to provide same with a cooling jacket. If the retentate is cooled down before being recycled into the fermenter, the cooling jacket may be saved when establishing a new fermenter, which will reduce the overall costs.

Furthermore, when cooling the retentate instead of or as an additional measure to using a cooling jacket, a better possibility of controlling the temperature distribution inside the fermenter is obtained. When cooling by means of a cooling jacket, some local cooling down of the part of the fermenting wort close to the walls of the container may occur whereas the part of the fermenting wort closer to the centre of the container may not be cooled down to the same extent.

When recycling the retentate into the fermenter it is preferred to direct the flow in such a way that an increased stirring of the fermenting wort is obtained. Thus, if the flow to be treated inside the membrane module is recovered from the bottom of the fermenter, it is preferred to recycle the retentate at a higher level, e.g. at the upper end of the fermenter, possibly at a level above the liquid surface. If desired, the recycling of the retentate into the fermenter may take place at a relatively high flow speed, e.g. by providing the opening with a nozzle or the like.

More stirring than by conventional fermentation *inter alia* makes it easier for the yeast cells to get into contact with the fermentation substrates, such as fermentable carbohydrates, whereby the time of the fermentation will be reduced. Furthermore, because of the increased accessibility to the fermentation substrates, the yeast cells will be less inclined to hibernate or die which improves the quality of the

yeast as a whole.

In one preferred embodiment of the present invention the yeast cells are immobilized on a suitable vehicle so that free-flowing yeast cells are only present in the fermenting wort to a limited extent or not at all. The particles comprising the immobilized yeast cells are prevented or inhibited from getting into contact with the membrane, e.g. by means of a net having a smaller mesh size than the diameter of the particles and provided at the bottom of the fermenter. The advantage of omitting the presence of free-flowing yeast cells in the fermenting wort is that yeast cells do not cause fouling of the membrane having the effect of reduced flux and deteriorated selectivity.

Yeast cells may be immobilized in any suitable way known to the person skilled in the art. For instance, yeast cells may be immobilized as suggested in US Patent No. 4,305,765 by using sulphated polysaccharides (e.g. carageenan, furcellaran, and cellulosesulphate), polyacrylamide, sodiumalginate, polyvinylalcohol, cellulosesuccinate, or caseinsuccinate. In US Patent 3,860,490 it is suggested to use polymerized acrylates and methacrylates. Gelatine, acrylolylpolymers, or carboxymethylcellulose may also be used as the immobilizing material.

The flow recovered from the fermenter mainly has such a size and is treated with such an intensity inside the membrane module that in the fermenter the fermenting wort obtains a CO_2 concentration lower than the CO_2 saturation point at the given pressure and the given temperature. When the CO_2 amount is kept below the saturation point, no bubbles of CO_2 occur, and, in consequence, the production of foam on the surface of the fermenting wort because of ascending gas bubbles is avoided completely.

Usually, it is preferred to lower the concentration of CO_2 in the fermenting wort to a value considerably lower than the saturation point, e.g. to 4 g/l or less. The reason is that CO_2 is produced in the yeast together with ethanol in a equilibrium reaction by conversion of carbohydrates. A high concentration of CO_2 will thus result in a displacement of the equilibrium away from the production of ethanol, i.e. CO_2 has a product-inhibiting effect that results in a slower conversion. If the CO_2 concentration in the fermenting wort is reduced, the conversion velocity of the fermentable carbohydrates is increased, and, thus, the fermentation time becomes shorter.

In the following, the invention will be described in further details with reference to the attached drawing, in which the figure shows a flow chart on a plant having reduced or avoided production of foam on the surface of a fermenting wort.

In a fermenter 1, a fermenting wort is contained. Over a valve 2, the fermenting wort is transferred into a retentate chamber 4 of a membrane module 5 by means of a pump 3. Inside the membrane module, the retentate chamber 4 is separated from a permeate chamber 6 by a membrane 7 allowing the passage of CO_2. Together with pump 3, a pump 8 for obtaining a vacuum inside the permeate chamber provides a pressure difference over the membrane sufficient for essential transport of CO_2 through the membrane. The CO_2 containing permeate is led to a suitable receptacle not shown.

The retentate, which has a reduced CO_2 content in comparison to the content in the fermenting wort conveyed to the membrane module, is cooled in a heat exchanger 9 before being recycled to the fermenter 1. At the upper end of the fermenter a valve 10 for maintaining the desired pressure in the container is

provided.

At the beginning of the fermentation, initially a wort comprising yeast is led into the fermenter. The CO_2 concentration of the wort will increase upon the conversion of carbohydrates, and at a certain predetermined CO_2 concentration the plant described above is started. If desired, the plant may be started immediately after the fermenter having been filled in order to provide a stirring of the wort.

During fermentation, the plant is operating continuously. The amount of fermenting wort led into the membrane module and the pressure difference over the membrane is adjusted so as to obtain the desired degree of CO_2 removal.

At the end of the fermentation, the production of CO_2 drops. The plant is stopped and yeast cells are allowed to precipitate inside the fermenter. After removal of the precipitated yeast cells through valve 2, if so desired, the green beer is stored for a predetermined period. If desired, the green beer may be conveyed to another container for storage.

PATENT CLAIMS

1. A process for reducing or avoiding production of foam on the surface of a fermenting wort comprising
- recovering a flow from a fermenter containing a fermenting wort,
- treating the flow in a membrane module comprising a membrane allowing the passage of CO_2 so as to produce a retentate having a reduced CO_2 content, and
- recycling the retentate to the fermenter.

2. The process according to claim 1 wherein the flow of a fermenting wort is recovered from the bottom of the fermenter.

3. The process according to one of the claims 1 or 2, wherein the flow recovered from the fermenter has such a size and is treated with such an intensity inside the membrane module that in the fermenter the fermenting wort obtains a CO_2 concentration which is lower than the CO_2 saturation point at the given pressure and the given temperature.

4. The process according to claim 3, wherein the CO_2 concentration of the fermenting wort inside the fermenter amounts to 4 g/l or less.

5. The process according to anyone of the claims 1 to 4, wherein the retentate is cooled before being recycled into the fermenter holding the fermenting wort.

6. The process according to anyone of the claims 1 to 5, wherein the recycling of the retentate is effected in such a way that a vigorous stirring is provided.

7. A plant for fermentation of a wort having reduced or avoided production of foam on the surface, said plant comprising a container for the fermentation of a wort, a membrane module having a chamber for retentate and a chamber for permeate separated by a

membrane allowing passage of CO_2, means for providing a pressure difference over the membrane, means for providing fluid communication between the container for the wort fermentation and the chamber for the retentate, as well as means for recycling the retentate from the membrane module to the container for the wort fermentation.

8. The plant according to claim 7, in which the outlet from the container for the fermentation of the wort is provided at the bottom portion.

9. The plant according to claim 7 or 8, in which a cooling device for cooling the fermenting wort is provided after the membrane module but before the recycling of retentate into the container for the fermentation of the wort.

10. The plant according to anyone of the claims 7 to 9, in which the outlet for the fermenting wort is provided at a lower level than the inlet for recycling of the retentate into the fermenter.

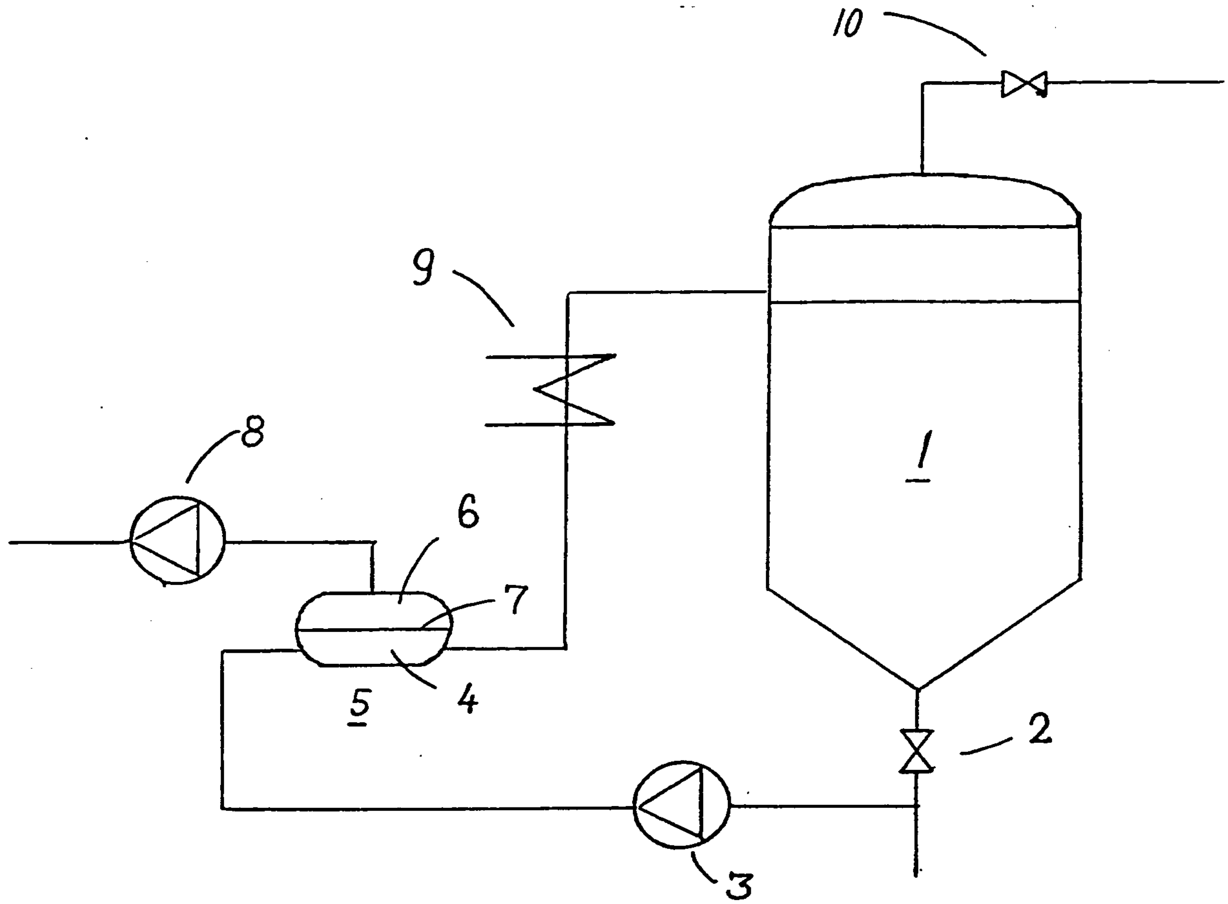

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C12C 11/00, C12C 13/02 // C12M 001/21
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C12C, C12M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5260216 A (HIROSE, TOSHIKI ET AL), 13 October 2000 (13.10.00), column 3, line 50 - column 4, line 5 --	1-10
A	DE 2535548 A1 (ANTHON, F., DR.-ING), 13 October 2000 (13.10.00) --	1-10
A	EP 0017650 A1 (BRAUPATENT UNIVERSAL AG), 13 October 2000 (13.10.00) -- --------	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2000	18 -10- 2000
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INTERNATIONAL SEARCH REPORT

Information on patent family members

01/08/00

International application No.
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